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ORIGIN AND PHYSICS OF THE ATMOSPHERE*

By H. LANDSBERG†

The earth has probably had an atmosphere ever since the planet came into being as an independent celestial body. At present, this atmosphere consists of permanent gases and variable quantities of water and solid dust. The water can be present in the solid, liquid, and gaseous phases. The composition of the gaseous matter in the atmosphere has been changing throughout the history of the earth. The origin and nature of the first atmosphere is a subject of speculation. The course of events is differently described in the light of various hypotheses for the origin of the earth.

The gassy envelope of the earth weighs about 5.1×10^{15} tons, about one one-millionth of the total mass of the earth. Assuming a hot initial stage of the earth, some postulate that the atmosphere had the same composition as the earth's outer solid layer, namely chlorides, nitrates, oxides, and silicocarbonates. After cooling below 1500° C., other constituents appear as free gases such as water vapor (from hydrates, hydrides, hydroxides), nitrogen, carbon monoxide, carbon dioxide, hydrogen sulphite, chlorine, hydrochloric acid vapor. Such gases are presently found in the exhalations of volcanoes. After further cooling to about 360° C., the water vapor was partially liquified and precipitated the less volatile constituents, leaving nitrogen, carbon dioxide, hydrogen, helium, and small amounts of oxygen. Much more carbon dioxide was present then than now. After cooling of the earth's surface to 50° C., plant life appeared and, through photosynthesis, produced during the approximate two billion years of subsequent history the major amount of oxygen now found in the air.

The initial stage is envisaged somewhat differently by Chamberlin (1949). Instead of a hot earth in the early stages, he believed it was formed by cold accretion of planetesimals. These, like present meteorites, would give off, upon heating, hydrogen, carbon dioxide, carbon monoxide, methane, nitrogen, sulphur dioxide, and hydrogen sulphide. The quickly dissipated heat produced by the impact of such small bodies upon each other could have produced the original atmosphere, later modified by photosynthesis of the plants.

These hypotheses are in flat contradiction to Tammann's (1924) idea of the origin of oxygen from originally present water vapor. The water vapor is supposed to have become partially dissociated at high temperatures into hydrogen and oxygen. The hydrogen is assumed to have escaped into space and the remaining water vapor to have condensed to form the ocean, leaving oxygen in the atmosphere in an amount not far different from the present one.

From nuclear considerations, especially based on the cosmic abundance of elements, Brown (1949) concludes that the mechanism during the formation of the earth was such as to prohibit the retention of substances which were originally present in gaseous state. This would indicate an almost entirely secondary origin of the earth's atmosphere as a result of chemical processes that took place after the formation of the planet.

On the basis of the only recently determined cosmic abundance of elements and gas kinetic calculations, which determine the escape velocity of gases from the high atmosphere, one can obtain a picture of the early planetary atmospheres prior to the long-term chemical interactions and photosynthesis. TABLE 1 shows the

* This paper, illustrated with lantern slides, was presented at the meeting of the Section, February 5, 1951.

† Research and Development Board, Washington, D. C.

compositions arrived at for some major planets of the solar system together with the mean escape velocities according to Kuiper (1949).

Spectroscopic observations permit us to verify, to some extent, the presence of these constituents in planetary atmospheres. These observations throw some light on questions of the terrestrial atmosphere. Such macroscopic evidence on the chemistry and physics of atmospheres of the other planets is useful, because the minutiae observed on the earth's atmosphere may throw our vision out of focus with respect to the bigger features of its behavior. In this connection, a few points of knowledge gained of Mars, our nearest neighbor planet, will be reviewed. The telescope, the spectrograph, and the thermocouple enable us to obtain observations leading to a deeper understanding of the basic laws governing planetary atmospheres. Hess (1950) has aptly summarized the available observations of Mars and their interpretation.

Mars has an atmosphere of nitrogen, carbon dioxide (about twice the amount noted in the earth's atmosphere), and water vapor. The pressure at the surface, in accordance with the smaller mass of that planet, is only 80 millibars, compared to a mean surface pressure of 1000 millibars on earth. The Martian "meteorologist" does not have to worry too much about the water vapor, in contrast to his tellurian colleague, for whom this constituent, which can be present in three different states of aggregation, is most troublesome. The Martian water vapor is mostly consumed by the formation of polar ice caps, which are a persistent feature, even though only a few centimeters thick. They quickly migrate in a few weeks from hemisphere to hemisphere upon the change from winter to summer between one or the other. Very little of this water vapor is stored in the atmosphere. We can draw the important conclusion that there is a very complete exchange of air from one hemisphere to the other between seasons. There is ample evidence that such is also the case on earth but many meteorologists still restrict their analysis of the general circulation of the earth's atmosphere to the northern hemisphere, because of the superior sets of three-dimensional observations there.

Mars occasionally shows cloud decks. Hess assumes that these consist of carbon dioxide particles. If the mean surface temperature on Mars is assumed to be 0° C., the dew point of CO_2 is reached at the height of the Martian tropopause in 45 kilometers with a temperature of −160° C. Winds observed in these cloud systems show cyclonic and anticyclonic circulation patterns with high pressure systems in subtropical latitudes and low pressure areas in higher latitudes, not unlike the conditions noted on earth. Radiation observations permit the deduction of temperatures at the surface of Mars, yielding the rough features for the northern hemisphere winter indicated in TABLE 2.

TABLE 1

MAJOR CONSTITUENTS OF ORIGINAL PLANETARY ATMOSPHERES AND ESCAPE VELOCITIES

Planet	*v (Km./sec.)*	*Major constituents in descending order of frequency*
Jupiter	61.0	H_2, He, CH_4, Ne, A
Saturn	36.7	H_2, He, CH_4, Ne, A
Neptune	23.8	H_2, He, CH_4, A, CO
Earth	11.3	N_2, CO_2 + CO, H_2O, O_2 + O_3
Venus	10.4	CO_2 + CO, NO, N_2, N_2O
Mars	5.1	CO_2 + CO, NO, N_2, N_2O

TABLE 2

SURFACE TEMPERATURE DISTRIBUTION ON MARS (NORTHERN HEMISPHERE WINTER)

Latitude, degrees	*Temperature, °C.*
60N	−40 to −50
20–35 N	0
20S	20 to 35
65S	0

Turning back to the earth, it may be appropriate now to look at the composition of the atmosphere as established by numerous analyses at the surface (TABLE 3).

Only three components show a rather wide range. All the others are found in almost invariable ratios at the surface. For these latter, no difference is found even

at the highest altitudes from which samples have been obtained. Chackett, Paneth, and Wilson (1950) have reported on analyses of air collected up to 70 kilometers from rocket flights. These show that helium, neon, and argon are found in almost the same proportion at those altitudes as at the surface. This leads to the important conclusion that complete mixing exists up to those heights.

Spectroscopic observations have shown the presence of oxides of nitrogen, methane, and sodium in the extreme reaches of the outer atmosphere (Elvey, 1950), where the composition may differ markedly from that

TABLE 3

COMPOSITION OF THE EARTH'S ATMOSPHERE AT THE SURFACE

Element	*Volume per cent*	*Range*
Nitrogen	78.03	—
Oxygen	20.99	20.86–21.00
Argon	0.94	—
Carbon dioxide	0.03	0.023–0.050
Hydrogen	0.01	—
Neon	0.0012	—
Krypton	0.0010	—
Helium	0.0004	—
Xenon	0.0001	—
Ozone	very variable	2 to 20 $\times 10^{-7}$
Water vapor	very variable	0–4
Dust	very variable	0 to millions of particles per cc.

at lower layers. The behavior of ozone is quite exceptional. Most of it owes its existence in the atmosphere to photosynthesis from oxygen under the influence of solar ultraviolet radiation. This process takes place at heights between 25 and 35 kilometers, where the ozone concentration is much larger than at the surface. This ozone has a notable influence on the heat balance of the atmosphere because of the heating effect of the short-wave ultraviolet absorbed in those layers.

While some water vapor has been noted in the high atmospheric layers above 10 kilometers, most of it is concentrated in the lower atmosphere. Its temperature-controlled cycle through various phases and its participation in the cloud formation and precipitation process are mostly responsible for the majority of specific weather phenomena observed on earth. It is the narrow zones of transition between phases that makes the daily forecast problem so difficult. In an atmosphere without water vapor, aperiodic changes from warm to cold would still superimpose themselves upon the diurnal and annual temperature cycles, but these events could be more readily anticipated than the multitudinous vagaries of water in the atmosphere. The storage and release of the latent heat of vaporisation and fusion of water vapor enter into all atmospheric energy exchanges in a most complicated fashion. Even without the phase transition, which is further complicated by condensation and freezing nuclei, the water vapor plays a major role in atmospheric heat transactions because of its absorption bands in the infrared.

Heat absorption in the long wave lengths also applies to the atmospheric carbon dioxide. While not so variable as water vapor, slower changes in the carbon dioxide content and effects of the absorption and scattering of radiation by dust have been adduced as reasons for major climatic changes in the course of geological history. The debate on whether these variations, presumably caused in the past by varying incidence of volcanic eruptions, have had such influences has not yet been concluded (Arrhenius, 1896; Humphreys, 1929; Wexler, 1951).

The thermal properties of the atmospheric layers have led to a general picture of the vertical structure of the atmosphere, as shown in TABLE 4, according to Flohn and Penndorf (1950).

Up to about 150 kilometers height, this structure has been fairly well verified from direct observations by balloon-and rocket-borne instruments. Further evidence has been obtained from measurements of the velocity of sound from big explosions (Cox, Attanasoff, Snavely, Beecher, and Brown, 1949). The conditions at higher levels up to 800 kilometers can be inferred from observations of radiowave propagation, me-

teors, and auroras. For these, and the even higher levels, we also have some notions from photometric and spectroscopic investigations.

It might be well to recall that 95 per cent of the mass of the atmosphere is below 20 kilometers and 99 per cent below 40 kilometers height. Most of the events of importance to the day-by-day weather changes take place in the troposphere and the lower and middle stratosphere. A direct participation of the higher layers, while suspected by some, has still to be proven. Even so, the importance of conditions in higher layers upon the transmission of radiowaves make studies of the ever-fluctuating ionospheric properties of great practical value. Here, a direct influence of changes in the solar radiations and corpuscular emissions has been shown beyond doubt.

For the study of the general circulation in the atmosphere, it would be very desirable to have an outside look at the earth, as we have had one of Mars. A bare beginning has been made by cloud photography from rockets downward. At present, the best pictures which have been obtained, from about 100 miles up, cover areas of a few hundred miles cross section only (Bergstralh, 1947; Newell and Siry, 1947). Even these permit a close correlation of cloud coverage to pressure patterns observed at the surface (Crowson, 1949). The potentialities of this new tool for meteorological studies are remarkable. For once, the meteorological analyst has available, at least for the one element (cloudiness), a continuous coverage instead of the discrete observations available from surface and sounding stations. The incomplete coverage afforded by the conventional observations, especially over ocean and sparsely settled land areas, is one of the major handicaps in meteorological work. These rocket observations may also give a glimpse into the future practice of meteorologists decades from now. With rockets travelling to higher altitudes, transmitting information by television, and with an adequate frequency of ascents, we might be able to put our science on a much firmer basis for its day-to-day tasks. It is pleasant to envisage this at a time when most people are preoccupied with a much less pleasant usage to which these rockets might be put.

In the meantime, the meteorologist has to try to interpret the data he has as best he can and formulate an adequate theory of general atmospheric circulation. Without such a theory, our science will forever remain empirical, and forecasting, especially for longer periods in advance, will remain a mixture of experience and art. Even in the theoretical field, however, our knowledge has rapidly advanced in recent years (Charney, 1950). A comparison between

TABLE 4

AVERAGE CONDITIONS OF ATMOSPHERIC STRATA, IN 45 TO 55° N LATITUDE

	Spheres	*Layers*	*Approx. ht. in Km.*	*Temperature °C. lower boundary*	*upper boundary*	*extreme values*	*Prevail. wind dir.*
Outer atmosphere	exosphere		>800	?	?	2000?	W?
	ionosphere	atomic	400–800	?	?	1200?	
		F	150–400	?	?	+60 to 1000	W
		E	80–150	−70	+50	+80 to −100	
Inner atmosphere		upper mixing	50–80	+50	−70	−80 to +70	Winter:W
	stratosphere	warm	35–50	−50	+50	−60 to +80	Summer:E
		isothermal	12–35	−55	−50	−45 to −65	
		tropopause	8–12	−40	−55	−35 to −80	
	troposphere	advection	2–8	+10	−40	+20 to −45	W
		ground	0.002–2	—	—	−40 to +40	
		bottom	0–0.002	—	—	−50 to +80	

the concepts of several decades ago and present ones will illustrate this.

In 1883, a spectacular event took place that made it desirable to explain observed atmospheric phenomena in terms of general atmospheric circulation. In August of that year, the eruption of Krakatoa threw enormous quantities of ashes into the atmosphere. These travelled from their origin near the equator in the southern hemisphere to all parts of the world. In the February 11, 1884, session of the New York Academy of Sciences, its President, Dr. Newberry, explained the phenomenon as follows:

"The system of circulation favors the spread over the whole world of dust thrown into the air in the tropics. The movement of the surface from west to east in the rotation of the globe is about 1000 miles per hour. The atmosphere, resting on the earth, moves with it but not quite so fast. It lags behind at the surface five or six miles an hour; at greater elevation, perhaps much more. This causes the great equatorial wind current, which flows from east to west in a belt, some 30 degrees in width, along the equator. At the same time the air in the equatorial belt is heated, rarefied and rises to be replaced by the cooler northeast and southeast trade winds which blow in along the surface of the sea. This causes a great movement in the atmosphere from the equator in a series of vertical circles toward the poles."

This is an obscure statement and it perhaps does not quite reflect the real knowledge at that time, because shortly thereafter Ferrel (1889) laid the groundwork toward a more adequate hypothesis.

Our modern concepts were formulated in a comprehensive fashion by Rossby (1941). He envisages, as a result of a combination of radiative processes and dynamic and kinematic properties of the atmosphere, a meridional three-cell system of circulation on each hemisphere: an equatorial cell with easterly surface winds and westerly upper winds; a mid-latitude cell with cyclonic disturbances and westerly winds at all levels; and a high-latitude cell with easterly surface and westerly high-level winds.* From a statistical analysis of 40 years of northern hemisphere weather charts, 1899 to 1938, Petterssen (1950) has been able to verify the essentials of this scheme; namely, a low-latitude steady state flow, where thermal and frictional components are in balance; a mid-latitude belt of cyclonic and anticyclonic disturbances; and a polar thermal circulation. Superimposed on these basic features are the seasonal changes, the variations introduced by land and sea contrasts, and the rather important, but often forgotten, patterns forced upon the atmosphere by the large mountain barriers. The modern concept incorporates also the high-speed substratospheric currents in mid-latitudes, the so-called jet streams, where winds, often at speeds exceeding 100 miles per hour, meander around the hemispheres.

It is a vastly more satisfactory, even if yet incomplete picture (Starr, 1948). Many subtleties still escape our analytic efforts. The interhemispheric exchanges are known to exist but they have not yet found their way into the theory of general circulation. For example, our climatic charts clearly indicate that, in the eastern hemisphere, there exists in winter a huge single cell with a tortuous air flow from Siberia to Australia, instead of a triple-cell meridional arrangement as called for by current theory. Work on these phenomena, however, is progressing at a rapid rate, and another decade should see great strides toward an explanation of the observations.

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* For lack of space we have to refer to the original paper for details of this scheme.

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SECTION OF PHYSICS AND CHEMISTRY

SOME SPECIAL TOPICS IN THE PHYSICAL CHEMISTRY OF HIGH POLYMER SOLUTIONS*

By BRUNO H. ZIMM†

The science of high polymers, the materials that make up plastics, proteins, and rubber, has been a most fruitful ground in recent years for the application of the methods of physical chemistry. This has been particularly true of the science of high polymer solutions. Solution behavior has always been an important part of physical chemistry. The phenomena encountered in high polymer solutions are sufficiently strange to excite our curiosity but sufficiently familiar to make possible the application, or to suggest the extension, of conventional methods. Add to this the fact that high polymer molecules can only be studied individually in solution, since the materials are practically involatile, and it is clear that the science of high polymer solutions is of first-rank importance.

A chemist is concerned with the behavior of molecules. A physical chemist is concerned with the physical properties of molecules and how these properties affect the materials made from them. The very first things he must know, after the gross composition of the material has been determined, are the size, shape, and internal arrangement of the molecules. The discussion here is about methods of getting information on these things.

The molecular weights of typical high polymers are so high that the usual methods of classical physical chemistry, *e.g.*, freezing point depression or boiling point elevation, are too insensitive. A method that has been successful and which is based on the same principles as the classical methods is the measurement of the osmotic pressure of dilute solutions. Even this method fails to give useful results for molecular weights greater than about one million. Until quite recently, however, it was the only

* This paper, illustrated with lantern slides, was presented at the meeting of the Section on February 6, 1951.

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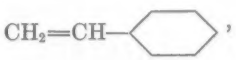
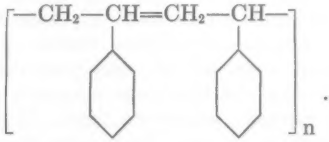
method applicable to the freely coiling chain polymers. In the last few years, the light scattering method has come into increasingly wide use. This method, which consists in essence only of measuring the fraction of a beam of light that is scattered by a solution of the material of known concentration and refractive index, is applicable to materials whose molecular weights range between 10^3 to 10^8, perhaps even higher. It thus covers conveniently the whole high polymer range.

When the molecular weight has been determined, the next step appears to be the examination of the shape and internal constitution of the molecules. Most high polymers, as the name suggests, are made by linking a large number of small molecules (monomers) together into a chain by means of a chemical reaction. For example, styrene,



polymerizes to give polystyrene, whose formula probably is:



The chain consists of a series of carbon atoms linked by ordinary valence bonds and bearing benzene rings and hydrogen atoms as side groups. It is known that in simple compounds rotation, usually with a certain degree of restriction, occurs around single valence bonds. Hence, we expect that the long chain of the polystyrene molecule will be able to coil into many different configurations, and we can only hope to express its "size" and "shape" in statistical terms.

Here, the mathematician has already been ahead of us. The classical problem of "random flights," in effect, is an idealization of the chemical problem. In the problem of random flights, a sequence of vectors, linked end to end in a chain, are assumed to be oriented each at random in space. Sometimes, the directions of each vector are assumed to follow a given distribution law. It is apparent that such a sequence of vectors would resemble closely the actual high polymer chain.

Some of the results of the ideal random flights problem are simple and directly applicable to the chemical problem. It is found that the mean square of the distance between the beginning and end of the chain is proportional to the number of links in the chain. The proportionality constant has been calculated for several models and its magnitude can give us much information about how much freedom of rotation exists about the valence bonds in the chain skeleton. It is also found that a directly measurable quantity, the mean square radius of the chain about its center of mass, is just $\frac{1}{6}$ the mean square end-to-end distance.

Chemical reactions seldom occur without the presence of side reactions. In the polymerization process, it is suspected that there are some side reactions capable of causing one chain to grow out of the middle of another, so that the whole molecule is a branched structure of random chains. It is, fortunately, a simple matter to extend the random flights method to this situation. The result, which is qualitatively obvious, is that branched chains have smaller mean square radii than unbranched chains of the same total weight. Moreover, the quantitative relations between mean square radius and degree of branching can be worked out.

There are two good ways of measuring the mean square radius of an actual molecule. One is a light scattering method, based on the study of interference effects in the pattern of light scattered from the solution. It is applicable only when the molecule is comparable in size to the wavelength of the light, but the necessary theory is simple and exact. The other method consists in measuring the "intrinsic viscosity" (a quantity measuring the increase in viscosity of the solution per unit concentration over that of the solvent). It is

intuitively obvious that the more extended a chain is the more it will hinder the flow of the solution of which it is a part. It is only recently, however, that the quantitative relations between the intrinsic viscosity and the mean square radius have come to be appreciated. There now seems to be good reason to think that for the larger high polymer molecules the intrinsic viscosity is directly proportional to the three-halves power of the mean square radius divided by the molecular weight.

We thus have two independent methods of measuring the mean square radius of an actual molecule, and we have a good method of getting its molecular weight, which is equivalent to getting the number of links in the chain. We therefore have the information necessary for the application of the random flights theory, and we may hope to get information about the amount of freedom of rotation about the carbon-carbon bonds in the chain, as well as answers to the questions about possible branches on the chain. There are, of course, some complications. One of these has to do with the fact that two links of the chain cannot be in the same place at the same time, a difficulty that was ignored in the mathematical theory. The discussion of this difficulty and the methods that may be used to circumvent it make a story whose last chapter is yet to be written. It is sufficient for the present article to say that it does seem to be possible to circumvent the difficulty by balancing its effects by another phenomenon: the tendency of chain elements to stick to one another when they are dissolved in a poor solvent. While it would take too long to go into detail here, it can be said that there is much circumstantial evidence for the correctness of the procedure.

Another difficulty arises from the heterogeneous character of the materials with which nature presents us and our imperfect abilities to separate them. Nearly every sample of a coiling chain polymer contains molecules which are all alike in chemical composition but which differ in molecular weight. This is awkward, because molecular weight is one of the fundamental properties that we are trying to use to characterize the material. These different molecular weight species may be partially separated from each other by solution and partial precipitation, but it is clear that we always are forced to work with average properties of a group of molecules. Different techniques may yield different averages. Thus, when a mean molecular weight is computed from osmotic pressure measurements, each molecule is counted equally with every other. The resulting average is called a "number-average" molecular weight. With light scattering, however, each molecule is counted in proportion to its weight, so that the heavier molecules are given more prominence in the average. This is called a "weight-average" molecular weight, and it is always higher than its osmotic counterpart. On the other hand, the mean square radii of the molecules are counted according to the square of their molecular weight by the light scattering technique, so that the result is not strictly comparable with either of the average molecular weights. To our great good fortune, however, the intrinsic viscosity turns out to measure a kind of average mean square radius that is only negligibly different from a weight average, so that we do finally have two quantities whose comparison will not be influenced by the variations in molecular weight of the constituent molecules in a sample of material.

In FIGURE 1 are shown some new data relating to branched polystyrene, these data being the work of Dr. Carl D. Thurmond at the University of California.* The intrinsic viscosity is plotted against molecular weight on logarithmic scales for two series of samples. One series are fractions of ordinary polystyrene, and the other are fractions from a special polystyrene in which foreign branch units (divinylbenzene molecules) were introduced. It would be expected that the chains bearing divinyl-

* This research was supported in part by the Office of Naval Research.

benzene units would have branches, and that the larger chains would have more divinylbenzene units and hence more branches. The mean square radii, and

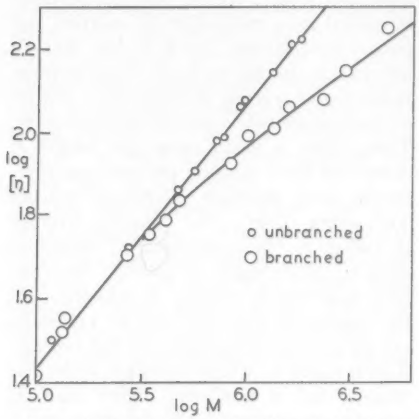


FIGURE 1. Plot of intrinsic viscosity against molecular-weight for fractions of branched and unbranched polystyrene.

hence the intrinsic viscosities of the larger molecules in the divinylbenzene series, should therefore be less than those in the pure polystyrene series. It can be seen that this is actually the case. We are now studying the quantitative aspects of this situation.

Other interesting information, the degree of restriction of rotation about the chain bonds and many more technical matters, can be obtained from these and similar data combined with mean square radii determined from light scattering. A more complete discussion has been given elsewhere.† In general, it can be said that the results confirm the usual picture of the coiling chain molecule and add quantitative values of some of its parameters.

We have given here a short discussion of some problems to illustrate what the physical chemist encounters when he tries to extend the domain of his science to include macromolecular phenomena. It should be clear that he has to draw not only from the classical material of his own field, but also from the work of mathematicians and physicists. When we consider that one of the main applications of macromolecular chemistry is to biological systems, we are plainly confronted with the creation of a new synthesis which may one day become a well differentiated field of knowledge. Whether the differentiation process is a desirable one is a question that we may well ponder.

† OUTER, P., C. I. CARR, & B. H. ZIMM. Light scattering investigation of the structure of polystyrene. J. Chem. Phys. 18: 830, 1950.

SECTION OF BIOLOGY

SOME EFFECTS OF ADENOSINE TRIPHOSPHATE ON THE CYTOPLASMIC STATE, DIVISION, AND DEVELOPMENT OF THE SEA URCHIN EGG*

By GEORG KRISZAT AND JOHN RUNNSTRÖM†

Adenosinetriphosphate (ATP) plays a central role in cell metabolism as a phosphate and energy carrier.[5] Its interaction with certain muscle proteins has been examined particularly.[9]

The writers studied the influence of ATP on the rigidity of the cytoplasm of the unfertilized egg of the sea urchin *Psammechinus miliaris*.[7] The stratification of the cytoplasm was followed in the centrifuge microscope. The final stratification of the cytoplasm obtained in the control at 4350 × g was called 100 per cent. The maximum slopes of the curves giving percentage stratification over time in the control were 61.5, and, in the presence of 0.003 M ATP in sea water, 39 per cent per minute. Eggs in Ca-free sea water also showed an increased rigidity of their cytoplasm in comparison with the control in normal sea

* On February 12, 1951, the Section of Biology presented a program entitled "Current Trends in Experimental Embryology." This paper was the first of three read at the meeting.

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water. Upon addition of ATP, the rigidity increased further (maximum slopes: for the eggs in Ca-free sea-water 40, for those in the same medium with ATP added 27 per cent stratification per minute).

Similar results were obtained with the amoeba, *Chaos chaos*. In the amoeba, however, an initial decrease in the rigidity of the cytoplasm was noted which is followed by the increase in rigidity. Phosphate, pyrophosphate, adenosine, or muscle adenylic acid exerted only weak or temporary effects. It is probable that mainly the cell surface is directly affected by ATP, whereas the changes in rigidity of the interior cytoplasm would be of secondary nature (see Lindberg[4]).

In further experiments on the amoeba, the authors tried to analyze the effect of Ca and of ATP on the cell surface by immersing the cells in solutions of basic and acid dyes. At pH 6.4, methylene blue penetrates into the cells rapidly in Ca-free but very slowly in Ca-containing medium. The opposite holds for an acid dye like aurantia. ATP (0.003M) blocks the penetration of methylene blue both in Ca-free and Ca-containing medium but allows aurantia to penetrate more easily in the absence than in the presence of Ca. More strongly lipid-soluble dyes, such as acridin orange of chrysoidin, are not affected by the Ca- or ATP-content of the medium. Similar experiments are being carried out at present with sea urchin eggs.

The effect of an exposure of unfertilized eggs to diluted sea water was appreciated by observing the membrane formation and cleavage of eggs which, after exposure for one hour to the diluted medium, were transferred to normal sea water (salinity: 25 per mille) and fertilized there. After pretreatment with 20 per mille sea water, the membrane formation still occurred in 100 per cent, but only 70 per cent of the eggs underwent cleavage. Moreover, this was rather atypical. The cells were flattened at the divisions poles and the contact surfaces of the cells were, in general, larger than normal.

If ATP (0.003M) was present during the exposure of the eggs to the diluted medium, the detrimental effect of the exposure was completely balanced. The eggs not only cleaved in 100 per cent but also exhibited a fully normal type of division. Exposure to 17.5 per mille sea water blocked the cleavage almost completely (1 per cent cleavage), whereas addition of ATP (0.003 M) brought the cleavage to 80 per cent.

Similar pretreatment of *Psammechinus* eggs with hypertonic medium (40, 35, or 30 per mille sea water) also lowered the percentage of cleavage. Again ATP proved capable of counteracting the injurious effect. In one experiment, for example, the percentage of cleavage was increased from 63 to 90 per cent by addition of ATP (0.003 M) to the hypertonic sea water (35 per mille). The cleavage type was also rendered more normal subsequent to addition of ATP. In another series of experiments, the eggs of *Psammechinus miliaris* or *Echinocardium cordatum* were fertilized in normal medium and thereafter transferred to hypertonic medium. The development of the eggs was followed in the hypertonic medium as well as in parallel samples in which ATP (0.005 M) was added after different times to this medium. In one case, for example, only 5 per cent of fertilized eggs of *Echinocardium cordatum* cleaved in 40 per mille sea water. Conversely, 52–55 per cent of the eggs cleaved when ATP had been added to the hypertonic sea water 10–30 minutes after fertilization. If ATP was added only 40–50 minutes after fertilization, the percentage of cleavage was lower, *viz.*, 34–37 per cent.*

Dinitrophenols and related compounds inhibit the division of sea urchin eggs.[1] In one experiment, with fertilized eggs of *Psammechinus miliaris* immersed in 6.10^{-5} M p-dinitrophenol in sea water, only 22 per cent of the eggs cleaved. Addition of 0.005 M ATP increased the percentage of

* Adenosine, muscle or yeast adenylic acid have later been found to have the same effect as ATP on fertilized *Strongylocentrotus droebachiensis* eggs subjected to hypertonic sea-water. These and other results will be reported in an article to be published in Experimental Cell Research.

cleaving eggs to 42. It is not only the increase in the number of cleaving eggs which is striking, however. One is also struck with the more normal cleavage pattern of the eggs to which ATP has been added.

The eggs from many females of *Strongylocentrotus droebachiensis* showed a strongly abnormal development, although a typical membrane appeared upon fertilization. The cleavage furrows, when appearing, were irregular and remained superficial. In the presence of ATP (0.003—0.01 M), 100 per cent cleavage occurred. Moreover, the eggs presented the normal cleavage pattern. The mesomere, macromere, and micromere layers were normally differentiated.[8]

It follows from the preliminary data presented above that ATP is able to remove certain kinds of block to cell division.

Presence of ATP also confers upon non-well-adjusted eggs a normal pattern of cleavage. This pattern seems to depend on a differential distribution of gel-forming material in the egg. Particularly, the formation of the micromeres is predetermined by an accumulation of gel-forming material at the vegetal pole of the egg, (see Lindahl).[3] This process seems to be favored by the presence of ATP. This effect may be related to the above mentioned increase in rigidity occurring upon addition of ATP to suspensions of unfertilized eggs.

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THE MECHANICS OF BLASTEMA FORMATION AND REGENERATION IN URODELE LIMBS OF REVERSED POLARITY*

By ELMER G. BUTLER†

Amputation of a urodele limb serves as the stimulus for a series of developmental events which ordinarily result in the complete regeneration of the limb. The first evidence of regenerative activity following amputation is the establishment at the distal end of the limb stump of an aggregation of cells known as the regeneration blastema. From the cells of the blastema arise all of the structures of the regenerate with the exception of nerves, which grow in from the cut ends of the old nerves of the limb.

Although many of the factors which govern the mobilization of cells to form a regeneration blastema are still obscure, we know from experimental evidence that the cells are local in origin[1] and that for the initiation of blastema formation the presence of nerves is essential.[2] Moreover, it has been shown that, under experimental conditions, a blastema may arise long after amputation and at a level far proximal to the point of amputation. Such is the case when a limb is denervated at the time of amputation, undergoes regression during a period of nervelessness, and later is rein-

* On February 12, 1951, the Section of Biology presented a program entitled "Current Trends in Experimental Embryology." This paper was the second of three read at the meeting. The third paper, by E. J. Boell, was entitled "Enzyme Development in the Embryos of *Amblystoma punctatum*." No abstract of this paper has been received.

† Department of Biology, Princeton University, Princeton New Jersey. The research for this paper was supported by an institutional grant-in-aid to Princeton University from the American Cancer Society.

nervated.[3] On reinnervation, a blastema is established and regeneration takes place. For example, a denervated limb amputated at the level of the metacarpals may regress to a level as far proximal as the head of the humerus. If it is then reinnervated, a blastema will form and regeneration ensue. Results such as these show that any level of the limb, regardless of the point where amputation took place, possesses the capacity for blastema formation.

Since the establishment of a regeneration blastema can be regarded essentially as a local phenomenon, the question arises as to the relation of the orientation of the limb to blastema formation. Normally, the blastema forms at the distal end of a limb stump. Suppose that the long axis of a limb were to be reversed, so that the original proximal end of the limb became the free end, would a blastema form under these circumstances? In other words, is the local character of blastema establishment such, that any level of the limb possesses the capacity for initiating blastema formation in a proximal as well as a distal direction?

A number of approaches have been made to a study of limb regeneration after reversal of the proximo-distal axis. Among others, Morgan,[4] Kurz,[5] Gräper,[6] Weiss,[7] and Milojevic and Grbic[8] have dealt with the problem. The results of these experiments varied, however, and a relatively small number of cases was studied. More recently, Butler[9] has obtained reversal of polarity in limbs of urodele larvae, using an operative method different than previously employed. Applying the technique of Butler to adult urodeles, Dent[10] has reported similar results.

In the present experiments, larvae of *Amblystoma maculatum* and *Amblystoma opacum*, ranging in length from 20mm. to 45mm., were used. The operative procedure of limb reversal was carried out in two stages. First, a small pocket was made in the muscles of the body wall just posterior to the shoulder region. The forelimb was amputated at the carpal level and the distal end inserted into the previously prepared pocket. This procedure was carried out with the animal narcotized, and light narcosis was continued for several hours until initial healing of the limb into the pocket had been accomplished. The second stage of the operative procedure consisted in the amputation of the limb slightly below the head of the humerus. This amputation permitted the proximal end of the upper arm to swing free as the new distal end of a limb transplant. Thus, in the transplant the original proximo-distal axis of the limb was completely reversed.

One hundred and eight successful operations of limb reversal have been performed. From these reversed limbs, fifty-two regenerates have been obtained and studied; forty-one cases were sacrificed and fixed for a study of histological alterations antecedent to the actual regeneration; and fifteen transplants underwent extreme regression.

Following the amputation through the upper arm, epidermal healing takes place rapidly. There are, however, no immediate evidences of blastema formation. On the contrary, since the reversed limb is nerveless, regression begins at the free end of the transplant and proceeds toward the body. In all aspects, this regression resembles that which always takes place in a normally oriented nerveless limb after amputation. In this case, however, it must be remembered that, in contrast to the normal limb, regression proceeds in a distal direction, in terms of the original polarity of the limb. When examined histologically, regression appears to be the result of a progressive dedifferentiation of cells, beginning at the free end of the transplant and progressing toward the body. Much cytolysis occurs and the resulting material is presumably removed from the site by the blood stream.

Regression ordinarily continues till the elbow joint is reached. Then one of two events occurs. Either a blastema is established and regeneration proceeds, or the transplant temporarily assumes the character of a non-regenerating appendage. In

the latter case, if the extreme tip of the transplant be amputated, a blastema will soon be formed. This operation consists essentially in the removal of a remnant of the humerus at the original elbow level. This bit of humerus, when it persists, serves as some sort of block to blastema formation. The exact nature of the block, which may well be other than mechanical, has not been determined and deserves further investigation.

The histology of blastema formation (irrespective of whether it was necessary surgically to remove the last remaining bit of humerus) has been studied in a series of cases fixed at appropriate periods. Establishment of the blastema on a reversed limb, after termination of the period of regression, resembles closely the same activity at the distal end of a normally oriented limb which has undergone regression, followed by reinnervation. In other words, as nerves grow out into a limb, which has been reversed by the method described above, regression ceases and blastema formation takes place. As yet, no detailed study has been made of the exact source of nerves which innervate the transplants, or of the pattern of innervation within the reversed limb.

In addition to its remarkably normal aspect, a significant feature of blastema establishment is the alteration which takes place in the formed tissues subjacent to the blastema. The perichondrium at the tip of radius and ulna disappears, the cartilage matrix undergoes dissolution and cartilage cells are freed from their capsules to mingle indistinguishably with the cells of the blastema. Similar changes of a dedifferentiative nature overtake the other tissues of the limb immediately beneath the blastema. There is present, therefore, the same intimate relationship between the tissues of the limb stump and the developing blastema which is to be found in normal regeneration.

The first evidence of morphogenesis is the lining up of cells within the blastema preparatory to cartilage formation. As skeletal elements of a new hand and digits are mapped out, indentations on the surface of the blastema indicate the positions of the first digits. With the progress of development, repair of the ends of radius and ulna takes place. Gradually, carpals, metacarpals, and phalanges are established. The end result is the formation, at the original proximal end of the forearm (the free end of the transplant), of a four-digit hand with wrist. In fact, the situation is such that carpals are present at both ends of the radius and ulna. At the pocket end of the transplant, there remain some of the original carpals of the limb, while at the opposite end are the newly established carpals and associated structures.

The establishment of a hand on what was originally the proximal end of the forearm is not, in the strictest sense of the term, regeneration. The structures which develop, under the circumstances of these experiments, are not ones that replace structures which were originally present at the level concerned. Rather, structures characteristic of the distal end of a limb develop at the proximal end, which, under experimental conditions, has come to be the free end of an appendage. Likewise, in a strict sense, it cannot be said on the basis of the experiments thus far completed that the proximo-distal axis of the entire forelimb has been reversed. Since the upper-arm segment of the reversed limb underwent regression to the elbow, it is only the forearm portion of the transplant which has exhibited the capacity to form a blastema after the reversal. These are matters which deserve further attention. If reinnervation of the free end of a reversed limb could be secured *before* the upper arm region had undergone extensive regression, would a blastema form, and what would be the character of the regenerate?

The precise morphological characteristics of the hands which have developed on the reversed limbs in these experiments, and the problems of symmetry which they raise, cannot be discussed in any detail at this time. A number of four-digit hands

have been obtained which, in completeness of morphological detail, compare favorably with a normal four-digit hand. Muscles are present and, although no coordinated movements have been observed, the digits of some cases exhibit mild flexion and extension of a rhythmic nature. In contrast to the cases with well-formed four-digit hands, are those which exhibit various sorts of malformations. In some cases supernumerary digits are present; in other cases digits are lacking. Also, irrespective of their number, be it normal or otherwise, the digits in various cases show varying degrees of size and morphological completeness.

The results of these experiments are of interest and significance not only because they demonstrate reversal of limb polarity and the capacity of the proximal end of the forearm to give rise to distal structures, but also because they emphasize the local nature of certain aspects of regenerative activity. Nevertheless, the phenomenon of limb regeneration as a whole can by no means be regarded as dependent solely on local activities.

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THE EFFECT OF CORTISONE AND ACTH ON EXPERIMENTAL SCURVY IN THE GUINEA PIG*

By G. A. HYMAN, C. RAGAN, AND J. C. TURNER†

Experimental scurvy was induced in the guinea pig by an autoclaved diet prepared by the method of Wolbach and Howe. Cortisone was administered to one group, ACTH to a second group, and one group remained untreated. In all of these animals, the adrenal ascorbic acid at death was too low to be measurable.

The effects of cortisone and ACTH were quite similar. The onset of the general manifestations of scurvy was delayed in the treated animals for approximately one week, although the majority eventually died with evidence of scorbutic lesions. Similarly, the extent of the hemorrhagic phenomenon was decreased in all the treated animals. Furthermore, prolongation of life was evident in the treated groups, with the cortisone-treated animals living approximately five days longer than the untreated controls, in which the average duration of life was 21.9 days. The ACTH-treated animals lived the longest, an average of 29.8 days from the start of the scorbutic diet and 20 days from the introduction of ACTH injections.

The absolute adrenal gland weight and the ratio of adrenal weight to body weight were increased above normal in all scorbutic animals, being greatest in the ACTH-treated and nearest the normal in the cortisone-treated group. The normal,

* This paper was one of five presented at a symposium entitled "Recents Experimental Studies with ACTH, Cortisone, and Related Steroids" held by the Section of Biology on November 13, 1950. Abstracts of the other four papers were published in the December and January TRANSACTIONS.

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average paired-adrenal wet weight was 145 mg. The scorbutic adrenal weights averaged 315 mg., the cortisone-treated adrenal weights averaged 225 mg., and ACTH-treated adrenal weights averaged 550 mg. The ratio of adrenal weight in milligrams to body weight in grams for the normal was .46, for the untreated scorbutic animal, 1.2, for the cortisone-treated, .74, and for the ACTH-treated, 2.06. This indicates a four- to five-fold relative increase in the adrenals in the ACTH-treated animals, corresponding closely with the absolute increase in size.

Microscopic studies of the adrenal gland in the ACTH-treated animals revealed intense hypertrophy and increased granularity interpreted as indicative of an actively secreting gland. Further evidence of secretion of cortisone-like steroids n the ACTH-treated group was provided by the initial weight gain paralleling that of the cortisone-treated animals, and also by production of pulmonary edema terminally. In addition, the protective effect of cortisone was duplicated by ACTH. Thus, the evidence seems to indicate (1) that cortisone-like steroids can be produced by the scorbutic guinea pig despite absence of measurable adrenal ascorbic acid, and (2) that the administration of cortisone and ACTH ameliorate the manifestations of scurvy in a parallel fashion, by a mechanism as yet unknown.

SECTION OF MATHEMATICS AND ENGINEERING

ERROR ANALYSIS FOR MATHEMATICAL MACHINES*

By F. J. MURRAY†

1. In order to study the problem of error in mathematical machines, one should appreciate its position relative to a number of larger topics. This means one should keep in mind the relation between these machines and mathematical analysis and the application of the latter to science and technology. For the physical sciences, mathematical analysis represents the method by which fundamental research is integrated into a coherent body of knowledge which we call a science. In addition, the application of such a science to technology presents complex mathematical problems which must be solved with ease and dispatch if a scientific design is to be obtained.

The modern applications of mathematical analysis are in general of such a complexity that mechanization is a matter of necessity and not merely one of convenience. It is essential that tedious computations be performed mechanically, since, otherwise, they would be overwhelming, and analysis itself would not be used.

One should understand mathematical analysis, however, in the broad sense. This is not merely a matter of numerical procedures. Mathematical analysis concerns itself with a broad class of concepts, abstractions with a specified logical structure, whose realizations appear in the various applications. Science presents unified theories in terms of these concepts, technology applies these theories also in these terms.

These concepts are necessarily quantitative but not necessarily numerical, although our elementary educational methods may give a misleading impression in this regard. For instance, it is customary to present the notion of function as a derived notion based on the notion of number. A familiarity with modern mathematics, however, shows that one can regard the notion of function, subject to various operations, as fundamental, and the values of the function may be a minor concept. Indeed, other num-

* This paper was presented at the meeting of the Section on February 16, 1951.
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bers associated with a function may be more important, for instance, the frequencies present in the function or their coefficients.

We see then that mathematical machines must be capable of handling not merely computational procedures but the wide range of mathematical concepts needed in modern science. Furthermore, in complex situations, we frequently need basic existence information which is not available from current theory. Classical mathematical analysis often simplifies the topics it deals with in the interest of logical symmetry, and ignores many possibilities. In applied mathematics, however, these nonsimplified problems do occur, and, consequently, one needs basic existence information in them.

To sum up, we need machines to handle mathematical concepts in the development of science, its application, and in the development of applied mathematics itself. (A list of current devices is given in ref. 1.)

2. By means of mathematical machines, we obtain information concerning mathematical concepts by constructing specific realizations. These realizations may be of two sorts. In digital computations in general, the concepts are realized by numerically valued functions or similar relations containing the essential quantitative information in numerical form. Modern automatic sequence digital computers permit tremendous flexibility in the realization of such numerical concepts. When, however, the range of desired concepts is more restricted, a certain saving in first cost and set up can be obtained by using continuous devices in which more concrete realizations are utilized. These continuous or "analogue" computers are particularly useful in cases where a general survey of a situation and a considerable amount of qualitative information are desired. For instance, a specific kind of a device may have a number of "behavior patterns" possible and others impossible, or a flow of liquid may have various flow patterns. An analogue computer may quickly tell us about these.

Now, it is reasonably evident that a mathematical device must be constructed for a certain range of problems. It is because this possibility of range is present that procedures based on mathematical machines may be substituted for a much more costly experimental program. Decisions and adjustments can be made on the calculating devices very cheaply compared to the corresponding experimental work. This is the customary justification for the use of computing machines in engineering design, and there is an analogous justification in the case of pure science. A device with such a range has the essential properties of the abstract mathematical concepts which we use to understand nature. For instance, when a differential analyzer is completely set up and the initial conditions specified, it may represent the behavior of a specific device under specified circumstances. Varying certain inputs may correspond to changing these circumstances, while certain other adjustments may yield the equivalent of changing the device itself. Notice then that flexibility of the computing device corresponds to a process of repeated abstractions, until we see that the differential analyzer itself corresponds to, say, the abstraction represented by all differential equation systems involving a certain number of variables and a certain specified set of operations.

In general, then, we have a situation in nature to be studied, a mathematical description of it, and a mathematical device to represent the latter. One of the most important things to appreciate is that the original situation is two steps, and not zero steps, removed from the computing device. One not unusual method of error analysis consists in saying that since both of these are realizations of the same mathematical concepts with errors, they must be accurate images of each other. Unfortunately, errors do not work out this way. The difference between two independent random variables will have a higher variance than either variable. Actually, the mathematical device is an inaccurate realiz-

ation of certain mathematical concepts which in turn offer a somewhat inaccurate description of the original situation. One does not improve matters in a case like this by cancelling errors with errors. Improvement can only be obtained by making the mathematical description of the original situation more precise and making the mathematical machine a more accurate realization of the concepts.

But the last statement indicates what the error problem is in computing devices. The problem of error in a computing device is the problem of determining the discrepancy between the mathematical concepts involved and the machine realization, not between the two "analogues." The last would be an effort to short circuit science.

To sum up our discussion to date, then, we see that the modern applications of mathematics, because of both their size and their complexity, require the use of machines. The correct use of these machines requires a careful study of the difference between the actual realization and the concept intended.

3. One can classify the errors of mathematical machines into two general types. Type one is due to either a mistake on the part of the operator or to a malfunction or failure of the machine. These are in general, but not always, large and erratic. They can be treated by probability methods, but clearly the best way to handle them is to detect them and eliminate them. Type two errors are due to inaccuracies of the device. Individually, these may be small, but their collective effect is probably the most important limitation on the size of the device and of the problems that can be considered.

In regard to the first type of error, I would like to point out the responsibility of the designer with regard not only to machine malfunctions and failures but to operator errors as well. The effective use of a mathematical machine must always involve checking against all types of errors, and the design of the machine should permit and even facilitate checking. This may seem at the moment a wild dream but, certainly, experience has indicated that this design requirement will have to be satisfied in the future.

This means, then, that the designer not only will prepare carefully maintenance and testing procedures which will prevent operation with components below a necessarily high standard, but will also consider standard checking procedures for the set up and operation of the machine by the operator.

Mathematical machines combine both considerable complexity and flexibility of operation. It is this combination that makes checking so necessary. If one makes the rather usual comparison with a telephone exchange, one should also point out that every connection of the latter is immediately checked by two people. Furthermore, a single failure is of slight importance. On the other hand, a single error on the part of the operator or a single malfunction will invalidate the complete output of a computing device for a considerable time.

One good example of the difference between the requirements for an ordinary device of even considerable complexity and a mathematical machine is the following. It is not unusual to obtain flexibility in interconnecting various components in a machine by providing a patch bay or jack panel similar to a telephone switchboard. There are certain advantages for this in the case of a small device, or in the case of a telephone switchboard where each connection is immediately checked. For a machine which must handle complicated mathematical problems, however, it has the following disadvantages:

a. There is no reasonable method of checking the set up of a problem except by a long tedious tracing of cords.

b. The machine is out of operation during the set-up time.

c. If the problem has to be taken off the machine and put on again, the whole set-up procedure has to be repeated.

d. Jacks and cords are the kind of

equipment which does not age gracefully. Cords develop noises and swinging shorts that are particularly unpleasant.

A good example of careful attention to the question of interconnection is provided by certain recent additions to the linear equation solver constructed by Mr. Robert Walker of the Watson Scientific Computing Laboratory at Columbia.[9] The correct functioning of this device depends upon 936 switch contacts. The operator can check that all contacts are made by a simple sequence of 12 resistance readings. This is a regular procedure which can be carried out in less than a minute when no trouble is present.

In general, one can point out that, for interconnections, objections (b) and (c) above can be met by providing set-up plug boards instead of a patch bay. This does not assist in checking procedures against operator errors, however, and the plug boards in a large laboratory can introduce a storage problem. A punch-card system of setting up the machine would probably be preferable.

The best type of checking against personnel mistakes is by counterchecking by another operator. This means that, if operator A is supposed to follow a certain set of instructions, operator B checks by taking the result and reconstructs the set of instructions. Another type of checking is that of duplicating the original set of instructions and comparing the results. This is frequently a less expensive method than the first but there is a regrettable tendency for duplicating errors.

One method often used for checking a set up is the use of a test problem. This is on the whole not a good way of doing it, although if no facilities for other checking methods are available, it may have to be used. A particular test problem may be insensitive to many aspects of the general set up and errors can occur without indication on the test problem. A careful analysis of the situation, however, may justify the use of a test problem for checking purposes.

To sum up then, concerning problems of type I. It is a major responsibility of the designer of the equipment to provide testing procedures which will insure against undetected malfunction and failure and also facilities that will permit standard checking procedures against personnel errors. It is not difficult to provide such facilities.

4. The second type of error, *i.e.*, that due to inaccuracies, has to be accepted even when detected, and it is not the effect of a single error which must be considered but the combined effect of a large number of such errors. The analysis of these is definitely a mathematical matter. Because of the variety of mathematical devices it may seem that a different analysis is necessary for every machine or, perhaps, for every problem. There are principles, however, which have a broad range of application, and we will try to illustrate these with examples.

In the first place, one should appreciate that the answer desired cannot involve an error analysis for each individual solution. This would obviously be more expensive than the solution process. Instead, one must depend upon a statistical answer of some kind. This is to be expected in view of the fact that a number of variables upon which the error depends are clearly chance variables. For instance, noise and accidental variations from prescribed values such as occur in resistors are chance variables.

It is clear then that the error analysis of inaccuracies must have a probability basis. With regard to those inaccuracies which are due to chance, one is hopeful that the usual theories are applicable, since one has a large number of apparently independent variables. In view of their relative smallness, one can expect that the total error is linear in these variables, and then the situation can be covered by well-known methods.

In addition to these chance variables, however, there are other factors which enter into the error. One may have delib-

erately introduced errors to permit the problem to be solved or conveniently solved. For instance, one of these is the truncation error in the digital solution of systems of ordinary differential equations. Another case frequently occurs in the computing portion of control apparatus, however, where a deliberate simplification is made in the mathematics of the problem in order to simplify the apparatus and cut down other inaccuracies.

This kind of inaccuracy has the advantage that it can be reasonably well estimated. Again, like the chance variables mentioned above, we may hope that the complete error is linear in these inaccuracies to an accuracy adequate for error analysis. However, linearity must also be understood to include linearity in time derivatives. Thus, we have a system of differential equations for the error in general, a situation which has been studied in numerous instances.[2, 6-8]

5. We have seen that chance and other inaccuracies occur in the solution process. We want to know not just these inaccuracies, however, but their total effect on the solution. Now, it is true that, in general, chance inaccuracies in components can be considered as independent of the particular problem to be solved. The non-chance inaccuracies, however, generally do depend on the particular problem, and, what is more important, the way in which these inaccuracies contribute to the total error depends on the particular problem and the way the problem is entered into the machine.

Let us consider those factors in the problem which affect the way in which the various inaccuracies contribute to the complete error. For instance, in the solution of a linear system of equations, algebraic not differential, one can show that the most important factor is the size of the smallest characteristic root of A*A, where A is the matrix of coefficients and A* the transposed conjugate of A. This has been shown for certain digital methods by Goldstine and von Neumann.[3] It can also be shown, by means of the equations of motion of a linear equation solver of the continuous type, that the error in these will depend almost exclusively on this least characteristic root.[4, 5] The error lies almost entirely in that direction which permits it to be biggest.

Another example where it is possible to specify the factors in the given problem which determine the way in which the inaccuracies contribute to the total error is in the case of a linear system of differential equations with constant coefficients. This has been studied by F. H. Raymond,[8] but the result pertinent to our immediate discussion is a recent one of Dr. Kenneth Miller and myself. One can show that a system of this sort is particularly sensitive to inaccuracies when multiple frequencies occur in the initial equation. It is hoped that corresponding analyses can be made in the more general cases.

6. The invariant character of the above-mentioned factors is evident, and any mathematical investigation of these problems endeavors to establish what aspects of a problem are independent of the particular mathematical choices that have been used to describe it. For instance, we can in general choose the variables in a particular problem in a wide variety of ways, but the frequencies which appear in the solution when they occur will not be affected as long as we retain the same independent variable.

The machine significance of this variation is immediately obvious. The possibility of changing variables and scales in different parts of the problem corresponds exactly to the freedom we have in setting the problem up in the machine.

Consequently, we have two kinds of factors which control the way in which the inaccuracies of the device build up into the total error. One of these kinds consists of those factors which are invariant under set up, and we must evaluate the way each of these controls the build up of error due

to inaccuracies. The other factors to be studied involve the way in which the problem is set up on the machine, and here the objective is not merely to evaluate the error but to obtain the set up which minimizes the error.

This, however, indicates clearly the mathematical attack for these problems. We must investigate the invariant structure of the problem, show how the invariants control the build up of effect of errors and, by studying the non-invariant aspects, establish the best method of setting the problem on the machine. The last corresponds to something of a simplification, however, since the practical problem one faces invariably involves a compromise between convenience and maximum accuracy.

7. While the above offers a general plan of attack on the question of accuracy for continuous computers, it necessarily avoids the question of the accuracy of individual solutions. In theoretical mathematical investigations in particular, this last may be of considerable importance. In fact, there are two problems here. One is to estimate the error in the solution. The other, which is more ambitious, is to refine the given solution to obtain a more accurate one.

Here it seems necessary to develop a method of supplementing the process of using the continuous computer by a digital process. One can show in a number of cases that one can set up a computing cycle involving (a) the use of the continuous computer to obtain an approximate solution, (b) the expression of this approximate solution in numerical or analytic form, (c) the digital computation of the error, and (d) the set up of a new problem for a correction to the solution which can be solved on the continuous computer. If there is an effective change in scale between the original problem and the correction of (d), then we have a computing cycle which will permit us to obtain any desired accuracy by continued repetition, and which, if just one cycle is used, can be used for error estimation processes. A good example of such a cycle is given by the usual process of solving simultaneous linear equations by continuous computers. (*Cf.* Ref. 4, p. 90, 1st edition, pp. III, 18–19, 2nd edition.)

8. The above discussion of science is, of course, far more optimistic than most of those which have received attention in recent years. The expanding universe is supposed to receive its momentum from atomic energy in its most regrettable form. Perhaps I should also regret the lack of philosophical content in this talk. The fact is that I do not regard these machines as substitutes for the human brain, much less the human mind. They perform essentially mechanical tasks which are too tedious or too expensive for human effort, or, like the steam shovel, they can do a bigger job. They are tools subject to the human will, which can be used for good or evil.

To sum up, then, the content of this paper, the information available from mathematical machines is needed for scientific, technical, and mathematical progress. The proper evaluation of this information requires a careful error analysis. Errors are of two types. Type I errors, involving malfunction, failure, or personnel errors are a proper charge of the designer, who should provide facilities for testing proper operation and also for adequate checking against personnel errors in the operation of the machine. Type II errors require a mathematical analysis of the given problem into its essential invariants and its variable aspects. The inaccuracies in the machine contribute to the final error in a way determined by certain of these invariants. The variable aspects are to be utilized to obtain the best possible set up of the problem on the machine.

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SECTION OF PSYCHOLOGY

APPLICATIONS OF PSYCHOLOGY IN THE FIELD OF GUIDANCE*

By ROBERT H. MATHEWSON†

The report of the University Commission to Advise on the Future of Psychology at Harvard, entitled "The Place of Psychology in an Ideal University," is pertinent in a number of ways to the topic of this paper. As a preliminary to my remarks, I should like to quote a fairly short statement from it:

"Most of the current reports and policy statements on education show an almost exclusive concern with curricula and their presumed effects. No doubt well meant, this ignorance of the realities produces a strangely impractical and doctrinaire effect. Actual experience in a dean's office (or in a college physician's office) reveals quite another set of considerations, namely, the psychological adjustments of individual human beings, of teachers as well as students, to the processes aimed at in the curricula. Do not the motivations and personality of the student matter in education? Are we wise or even safe in relegating as negligible or unmanageable the varieties of student capacities, tastes, and temperaments? Does not this aspect of education in a free society need much more attention and explicit care? We insist that it does.

"So remarkable is the neglect of what psychology could even now bring to education that we may be tempted to 'correct' that neglect by compensatory exaggeration of all that psychology could do. Though we believe the gains to education would be very great, we doubt if they could come all at once. Certainly, psychology, with its present limitations, would be vulnerable to retaliatory criticism unless caution graces its promises of usefulness.

"Psychology should, and eventually will, supply a major part of the scientific foundation for the slowly evolving art of education. Dependable knowledge of the aptitudes and capacities of the pupil, and more important, his interests and enthusiasms, are incomparably more important for effective education of the individual from birth to maturity than are the so-called 'subjects' now 'taught' in our schools from nursery to university. Until we apply what we know of the psychology of learning to the individual, we shall be evading the essential issue, whether the evasion be via a free elective system or the mass exposure of all students in common to the same curriculum."

This rather strong assertion by the members of the Commission may seem surprising, in view of the fact that for a number of decades now, psychology has supposedly been applied in the field of education via the study of Educational Psychology, Child Development, and the like.

The belief that an essential function has been "taken care of," however, because certain courses have been listed among the offerings provided for undergraduate and graduate students in teachers' colleges and schools of education, obscures the fundamental fact that the major need for the application of psychology in education and in guidance has not been clearly recognized,

* This paper was presented at the meeting of the Section on February 19, 1951.

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even by educators and psychologists. Likewise, parents, employers, and citizens generally have failed to realize and to accept this need. Consequently, they have neglected to give to the schools and to school administrators the necessary mandate to do something about it.

Appraisal of the Need for Applications of Psychology in Education and Guidance. This fundamental need can be described very briefly: it is the need in the field of education and of guidance to provide professional aid to the individual pupil and his parents with problems of personal appraisal, adjustment, orientation and development.

Within this more general framework of need lie the special needs and correlative responsibilities of the school's guidance services, such as:

1. Knowledge by the pupil and his parents of his personal make-up in relation to developmental requirements and opportunities.
2. Selection by the individual of appropriate courses in line with individual characteristics and circumstances.
3. Evaluation of individual progress in school; satisfactory adjustment to school work; getting the most out of school.
4. Social adjustment to teachers, to other pupils, and in the family, and community.
5. Development of socially favorable attitudes and dispositions.
6. Selection of tentative broad area of preparation for ultimate vocational activity.

These are all related to the continuous and unified need for the appraisal, adjustment, orientation, and development of children and youth throughout the whole educative span.

Departing from a philosophy that saw the need for vocational guidance at major choice points rather late in the educative careers of most individuals, education then advanced to the point where it visualized guidance as a service which should not be remedial so much as it should be preventive in its early detection and treatment of personal maladjustments which might later be very difficult to remedy. This emphasis on the identification and treatment of problems for preventive purposes has been the great contribution of child guidance. Today, the problem is beginning to be seen largely as a question of developmental aid to all children, whether adjusted or maladjusted, whether normal or abnormal. This developmental process will have to deal with all the matters of adjustment, orientation, and development that occur at every stage of pupil growth, including educational and vocational guidance. Thus dealt with, the process incorporates an over-all controlling purpose of educating and guiding individuals to become self-directive and self-corrective, and the concept of either remedy or prevention loses its primary significance.

The Problem of Application or Implementation of Psychology in Education and Guidance. Consideration of activities of this nature, particularly guidance services, raises the question of the applications of psychology to guidance as we now have it and as we might have it, if we move in the directions indicated.

Clearly, if we are going to utilize our human resources to the utmost, by developing every individual to the utmost of his capacity, and at the same time, take into account his preferences, his value system, and his power for self-direction and self-correction, then we shall require an education, and in back of it a psychology, which has a pretty well-formulated theory of personality and of behavior, of techniques of individual appraisal, of methods of counseling in problems of adjustment and orientation, and of methods of individual development which go beyond what we now do in the way of either classroom instruction or individual guidance and counseling. The very delicate matter, for instance, of what degree of self-awareness and of self-direction an individual is capable of at any given stage of maturation, and how facts about himself can be communicated to him

in order to aid self-development rather than obstruct it, will be a central one in any educational process which takes seriously its mandate to be developmental rather than purely selective or determinative. There will be times and stages when an individual can be told certain things rather directly. There will be other times and stages when education and guidance must be quite permissive rather than directional.

In broad outlines, we are now faced with a triple problem in the application of psychology in education and guidance:

1. The time is ripe for a re-examination of psychological theory bearing upon personality development and a re-synthesis of what we already know into a formulation that can be effectively utilized in schools by administrators, teachers and guidance workers.
2. Coincidentally, there should be a re-direction of educational philosophy and policy so that it may be clearly understood, both by professionals and the public, what the revised purposes are and what the different allocations of responsibility can be among the various levels of the instructional and guidance process.
3. Fundamental in importance will be the pre-service and the in-service training of teachers, guidance workers, and school psychologists to perform the collaborative tasks of developmental psychology in education.

The Problem of Training. Our analysis of needs and the meeting of those needs for the application of psychology and guidance in education brings us to the problem of the training of workers to apply the psychology.

Having been long in the ranks of the practitioners as well as in those of the academicians, and even in those of the administrators and coordinators, I have my own convictions, not to say prejudices. It is possible some day that we shall have one field of practice which may be known by some such designation as "Psychological Services in Education," for which practitioners will receive a single form of basic core training that may branch into various "sub-specialities" in its final year. That may be the present tendency. Currently, however, we may not be quite ready for such a development in psychology.

As the key worker in guidance, I visualize the general guidance counselor occupying a post right behind the classroom firing line. These workers would be former teachers, carefully selected not only for academic and intellectual ability, which should not be subordinated, but also for their social sagacity and ability to deal with children and their parents in a natural way. These former teachers might then be given graduate training which would include a strong grounding in psychology, in educational policy and philosophy, in sociology, and in anthropology to the extent of at least one and one-half and preferably two years of study beyond the bachelor's degree, plus an interneship under careful supervision at the end of the graduate training.

In our current Graduate Program in Guidance and School Counseling in the Division of Teacher Education, New York City, we are attempting to offer a rather complete form of the kind of preparation of which I have been speaking. Our *pre-admission requirements* are for 12 semester hours in Psychology. The graduate program covers 30 credits in four main areas: Socio-Psychological Foundations; Measurement; Guidance Policy and Practice; and Related Electives. Pre-admission and general coverage requirements compel the student to have had courses in Personality Theory, Psychology of Adjustment and Development, Mental Hygiene, Abnormal Psychology, Diagnostic and Remedial Education, and the Individual and Society, in addition to more applied regular courses in measurement, counseling techniques, and field practice comprised within the 30 credit, Master's degree sequence.

This constitutes a program for the preparation of general guidance counselors who

can deal with common problems of pupil adjustment, orientation, and development, working very closely with teachers. Problems involving emotional disturbance and disorder, requiring intensive case work—individual or social—beyond the limits of the counselor's competence, are referred to the clinical school psychologist.

The gap between academic theory and educational practice is too wide at present in the field of psychology. It should be closed for the good of psychology, for the good of education, and for the good of American society. Those of us who are in the area of applied psychology in education and guidance need the help and support of fellow psychologists, of educational administrators, and of citizens in the community in the common purpose of aiding the highest self-realization of the American boy and girl, commensurate with social and moral demands and obligations.

DIVISION OF MYCOLOGY

THE DESTRUCTION OF WOOD BY FUNGI AND ITS PREVENTION—WOOD PRESERVATION*

By J. LEUTRITZ JR.†

Decay of wood is a phase of the carbohydrate cycle. Green plants are builders. They make sugars, celluloses, other complex carbohydrates, and lignin from carbon dioxide and water during the process of photosynthesis. Fungi and bacteria are destroyers. They act upon these materials after the death of the plant and break them down again into carbon dioxide and water. Decay is a fermentation or breakdown of the wood constituents, cellulose, and lignin by the enzymic systems characteristic of certain groups of fungi. The fermentation processes for the carbohydrates have been studied in great detail, and many of the steps in the chemical breakdown have been very well established. The chemistry of lignin, its synthesis and decomposition, is not so well understood. The role of living organisms in the breakdown of both constituents, however, is well recognized.

Early attempts to rationalize the decay process gave rise to some interesting concepts. Scheele and Priestly, respective discovers of the gases, chlorine and oxygen, conceived of an elemental, invisible substance called phlogiston. The loss of phlogiston from organic substances was thought to be the cause of decay. Carbonic acid gas was observed escaping from most fermentations. This gas, it was rationalized, must possess special cohesive properties, and its loss caused separation of the molecules. Another concept was conceived and championed by Liebig. Decay was defined as "a slow combustion produced by contagion, the infected bodies communicating a molecular motion to the atoms of the bodies with which they came in contact." This concept, called "eramacausis," coexisted with the biological theory of abiogenesis or spontaneous generation. Together, they dominated the thinking of chemists and biologists interested in the decay process until the combined researches of Debary (1856), Pasteur (1863), and R. Hartig (1874) showed the true role of living organisms in disease and decay processes.

A few wood destroying fungi, not economically important, belong to the *Ascomycetes*. Members of this group which are important in the staining and degrade of timber after it has been felled belong to the *Ceratostomellas*, *Penicillia*, and *Fusaria* species. The most economically important wood-destroying fungi are members of the *Basidiomycetes*. Numerous examples will be found in the families *Thelephoraceae*, *Hydnaceae*, *Polyporaceae*, and *Agaricaceae*. All of these groups have basidiospores borne on a characteristic hymenium layer.

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Many members of each of these families are known to cause decay of wood. Some are recognized universally as the cause of decay of downed timber. They are benevolent scavengers, along with insects, which clean the forest floor. Few of these fungi, relatively speaking, attack lumber and timber in use. Among the so-called "Hausschwamm" type, *Poria incrassata*, *Merulius lachrymans*, and *Coniophora cerebella*, cause considerable damage to foundation timbers of buildings under conditions favorable for decay. Others like *Lenzites sepiaria* and *Schizophyllum commune*, are frequently found on untreated southern pine and downed timbers if the material is held for long seasoning and storage periods. The first of these causes severe losses during storage, but the other is relatively unimportant in the decay of southern pine.

On creosote treated wood, railroad ties, paving blocks, telephone poles, and test posts, the organism which is isolated most frequently from material which has failed in service or in test plots is *Lentinus lepideus*. Another organism, *Lenzites trabea*, has been often isolated from poorly-treated southern pine and is universally found on untreated western red cedar sapwood. Isolations have also been made of *Fomes pinicola*, *Fomes roseus*, *Poria radiculosa*, *Poria microspora* and a few other unidentified isolates which have been tentatively assigned to the genus *Poria*. From test posts treated with low retentions of preservative mixtures of inorganic salts, the principal isolates have also been members of the same genus. All of these organisms, when tested in the laboratory, will cause losses of wood substance ranging in amount from 25 to 60 per cent by weight of a 5 gram test block within three months under conditions favorable for decay.

The two important factors which exert the greatest influence on growth of the organisms and decay are the temperature and moisture content of the wood. The maximum growth rate for different wood-destroying fungi on nutrient agar varies with the temperature. Growth on nutrient agar is inhibited at about 45° and 10°C for the most temperature-tolerant types. Maximum decay of wood, as measured by weight loss of wood substance, was shown in a paper by the author (1946) to coincide with the optimum growth temperatures determined for several of the same fungi on nutrient agar. The optimum range for most wood-destroying fungi is between 26–28°C.

Wood that is too dry or too wet will not decay. Decay does not take place if the moisture content of the wood is below 20 per cent on an oven dry basis. The maximum amount of decay takes place when the wood is initially at or slightly above fiber saturation. Decay of wood by certain fungi, namely, *Lenzites trabea* and *Poria microspora*, may take place slowly when the moisture content is over 80 per cent, but the fungus, *Lentinus lepideus*, will not attack wood which is that wet. Wood in contact with moist soil in a closed system contains 28 to 30 per cent of water, and the total quantity of water in wood blocks during exposure to decay fungi remained approximately the same regardless of the loss of wood substance. The volume of the blocks also remained constant. The irreversible shrinkage due to decay took place only upon exposure of the blocks to a lower relative humidity. The use of soil as a base for the culture with a view to better control of the moisture content of the wood during the decay period led to a laboratory-assay method, the soil contact culture technique. This basic method has gained wide acceptance both in the United States and abroad. This laboratory tool is now used at the United States Forest Products Laboratories and several industrial laboratories for basic studies of wood preservatives.

Many compounds were tried as preservatives of wood. Early Greek and Roman writers cite the use of astringents expressed from olives and the oils of cedar, larch, juniper, and nardbush. The use of mercuric chloride to protect the wooden fleets, first by the Dutch in the early 18th century

and approximately a century later by the British, was a disappointing failure. Two other salts, copper sulfate and zinc chloride, gained considerable popularity during the 19th century. Both are used today in mixtures with other salts, mainly, the chromates and arsenates. These salts enhance the preservative properties of the copper and zinc salts, and, in addition, the chromium salts impart rust inhibiting properties to the treating solution. The salts may also retain these properties after they are deposited in the wood. The insoluble chromate and arsenate complexes formed with copper and zinc in the wood assure greater permanence of preservative qualities. In these respects, they compare favorably in permanence with the insoluble oily types such as creosote.

"Kreosote," a term applied to oils heavier than water, obtained from the distillation of coal gas tar, was first mentioned as a wood preservative in a patent issued to Franz Moll in 1836. This patent, together with the Bethell patent (1838) for "Rendering Wood Cord, *etc.*, More Durable, *etc.*," was the basis for the most successful wood preserving practices. More wood is treated with creosote today than with all other preservatives combined. Unfortunately, creosote is a variable mixture of complex organic compounds. The determination of the permanent wood preserving properties of any given creosote within a reasonable time period is exceedingly difficult. Prior to 1912, the determination of the wood-preserving properties and toxicity of a large number of different creosote compositions and other preservatives was both costly and time-consuming. Furthermore, failures of inferior preservatives, as in the case of the Royal British and Dutch Navies, threatened maritime supremacy and jeopardized the national security. To screen out the inferior preservatives, laboratory assays using nutrient agar and wood-destroying fungi were developed in both Europe and the United States.

After 1912, large numbers of petri-dish assays of toxic materials were conducted at the U. S. Forest Products Laboratory. The test organism was first identified as *Fomes annosus* and is now referred to as Madison 517. Similar assays were run by the Bell Telephone Laboratories using a wide variety of organisms, including Madison 517 and a large number of non-toxic chemicals. Supplementing the work of the Forest Products Laboratory with Madison 517, the author, in an unpublished thesis, attempted to relate the toxicity to *Lentinus lepideus* with the chemical structure of various compounds. The use of the petri-dish test reached its zenith about 1929, when it was adopted as an unofficial American standard for testing the toxicity of wood preservatives.

The following year, a meeting of American and European investigators was held in Europe. Preference was shown for the Kolle flask technique using wood blocks over an agar nutrient base, and it later became the British and European standard. Falck, in 1927, was probably the first to use impregnated wood blocks for testing of wood preservatives. The use of wood blocks was adopted by the Bell Telephone Laboratories about 1930, when it was found that the results of outdoor-stake tests and petri-dish (agar) tests did not agree. A method for using impregnated wood blocks was developed and described by Waterman, Leutritz, and Hill, 1936. Its principal drawback was the lack of control over the moisture content of the blocks during the decay period. This difficulty was overcome by using a garden soil and wood at the supporting medium and substrate. Using the wood-soil contact culture technique, Addoms, Duncan, and Richards have shown, in a series of papers, 1947, 1948 and 1950, that the technique is an excellent laboratory tool for measuring the permanence of preservatives in treated blocks and exposure to pure cultures of fungi.

The fungi used for assays of wood preservatives in the laboratory are selected for one or more of the following reasons:

(1) Occurrence and frequency of isolation from service and test material.

(2) Demonstrated ability to decay wood under laboratory conditions after isolation.
(3) Ease of handling in pure culture.
(4) Behavior toward different chemicals.

The first three reasons for selection of fungi are obvious. The significance of the fourth reason deserves emphasis, because the behavior of fungi to different chemicals can be rather striking. *Lentinus lepideus* has been shown over and over again both here and abroad to have marked tolerance to creosote. The evidence is gathered from isolation experiments with

TABLE 1

Preservative	*Organism*	*Threshold concentration (lbs. per cu. ft. of wood)*
Creosote	*Lentinus lepideus*	4–5
Pentachlorophenol in petroleum	*Lenzites trabea*	0.12
Copper Naphthenate in petroleum	*Lentinus lepideus*	0.07*
Zinc chloride	*Poria incrassata* *Poria radiculosa*	>1.0
Acidic chromium, copper, and arsenic†	*Poria incrassata* *Poria radiculosa*	0.7
Acidic chromium, zinc, and arsenic	*Poria radiculosa*	0.8–1.6

*In terms of metallic copper.
†*Lentinus lepideus* was so sensitive to this mixture that the threshold concentration was less than 0.25 lbs. of total salts per cubic foot of wood.

infected, creosoted wood and comparative laboratory tests with other fungi. All laboratory tests confirm this tolerance and also show that the same fungus is relatively sensitive to copper salts. Another frequent isolate from creosoted material is *Poria microspora*. Compared to *Lentinus lepideus* it is inhibited by 20 per cent less creosote, but withstands ten times more copper sulfate in petri-dish agar tests. The behavior of other fungi toward preservatives has been treated by the more recently developed soil block assays. They show that there is considerable variation in the amount of chemical per unit volume of wood needed for protection against different fungi. A few selected preservatives and the wood-destroying fungi which show a considerable degree of tolerance to them when tested by the soil block technique are shown in TABLE 1.

Summary. Decay of wood is caused by a large number of fungi. These wood destroying fungi, with a few minor exceptions, are all members of the *Basidiomycetes*. Most of them function as scavengers of down timber on the forest floor. Only a few, relatively speaking, are economically important in the decay of lumber and timber in use.

The decay process is largely dependent on two factors, temperature and moisture. Depending on the fungus, decay may take place at temperatures between 10 and 45°C., providing the moisture content of the wood is above 20 per cent. Wood exposed to the prevailing ambient relative humidities in the United States contains 12–15 per cent of moisture. Decay occurs when the wood absorbs moisture because of rain, condensation, and humidity above 95 per cent and contact with ground water. Under such conditions, especially the latter, unless the wood is inherently durable, it should be treated with a preservative.

Many preservatives have proved successful for preventing decay under severe service conditions. The first and most successful of these was creosote. Two relatively new oil-borne toxics, copper naphthenate and pentachlorophenol, are proving of considerable value as special purpose preservatives. Salt mixtures, especially the acidic chromium copper and arsenic, and the ammoniacal copper and arsenic solution are building satisfactory service records. Other salt solutions of the more soluble or less potent type have been successful for treating wood above ground and where decay conditions are less severe because of the particular environment.

The original selection of preservatives prior to 1912 was by trial and error. Later, records of satisfactory service life of the treated wood offered a sounder basis for engineering decisions. As a result, while the distillates of coal tar (creosotes) proved to be satisfactory, a large proportion of the

materials tried as wood preservatives failed, sometimes with serious economic consequences.

Since 1912, the development of the petri-dish agar, Kolle flask and soil-block techniques using pure cultures of wood-destroying fungi has furnished a foundation for evaluating the toxicity, the wood-preserving properties, and the relative permanence of pure compounds and mixtures of these compounds. With information obtained by using these techniques and different fungi, bases for quality control of preservatives and for the development of preservatives for specific use are possible. The next major advance in the field of wood preservation will be in the correlation of results from laboratory techniques with the results from accelerated field tests and actual service performance.

*SECTION OF ANTHROPOLOGY**

TRENDS IN EUROPEAN ANTHROPOLOGY†

By ERWIN H. ACKERKNECHT‡

Of the four distinct centers of anthropology in Europe, I propose to discuss only Germany and France. British anthropology is easily accessible for those who want to inform themselves. Scandinavian anthropology is known to me only from the literature. My knowledge of German and French anthropology is more direct and dates from my student days. It was interrupted only through World War II. Thanks to the Viking Fund (New York), I was able to make an extensive survey of anthropology in western Germany during the summer of 1949, and to renew my French contacts.

In spite of their theoretical assertions, a great many anthropologists in all countries are just as provincial and naively ethnocentric as their lay brethen. I feel, in a quite unsentimental way, that anthropologists should be more interested in the work and ideas of anthropologists in other countries, because valuable work is done in all countries and fundamental answers have been unsatisfactory so far in all countries. I report on French and German ideas in the following without identifying myself with them, without regarding them as "ultimate solutions." I feel, however, that they are at least as worthy of consideration as the ideas professed in our country during the last 15 years.

France and Germany both have a distinguished past in the field of anthropology. German anthropology had a magnificent start in both its branches, physical and cultural, with Blumenbach and Georg Forster and their contemporaries at the end of the 18th century. It had an impressive comeback with Bastian, Virchow, *etc.* in the 1860's. It fathered the historical schools of Frobenius, Graebner, and W. Schmidt. German ethnographic contributions in Africa, South America, and Oceania are indispensables.

France was pioneering in physical anthropology with Broca and his school, in prehistory with Boucher de Perthes, Gabriel de Mortillet, *etc.* French sociology, through Durckheim, became deeply involved in anthropology. Durckheim's work in anthropology was continued by his nephew and collaborator, Marcel Mauss, who died only a year ago.

The work of Claude Lévi-Strauss, beyond any doubt the outstanding living French cultural anthropologist, is an interesting development of the Durckheim-Mauss tradition. Lévi-Strauss recently edited a selection of Mauss's essays. His monumental "Les structures élémentaires de parenté" (Paris, 1949) was praised in the

* The Section of Oceanography and Meteorology held a meeting on February 27 at which a paper was presented by W. J. Pierson. No abstract of this paper has been received.

† This paper was presented at the meeting of the Section on February 26, 1951.

‡ Department of History of Medicine, the University of Wisconsin Medical School, Madison, Wisconsin.

"American Anthropologist" as "the most important book in anthropology of this generation" that "does for social organization what the Origin of Species did for biology." The book deals with the different forms of preferential marriage. Marriage is regarded as the prototype of exchange.

Lévi-Strauss, who dedicated his book to Lewis H. Morgan, has, on the other hand, assimilated many other traditions besides that of Durckheim-Mauss. He has written most understandingly on Boas ("Ethnologie et Histoire"), on the psychological implications of primitive medicine ("Le sorcier et sa magie, L'efficacité symbolique") and on the application of linguistic to ethnological theory.

The publication of the notebooks of Lucien Lévy-Bruhl covering the last year of his life (1938–39) by Maurice Leenhardt, the well-known Oceania specialist, has revealed that Lévy-Bruhl intended to write a last book in which he wanted to renounce his theory of a "prelogical" and "specific" mentality of primitives. All human minds are logical. All make emotional as well as logical generalizations. Emotional generalizations assume states of "participation." These aspects of human psychology are more obvious among primitives.

"Être est participer." We find in the last work of Lévy-Bruhl the same strong awareness of the power and importance of social cohesion that is found in the whole Durckheim school, and that gives an almost mystical flavor to the otherwise so rational analyses of the "faits sociaux" by the school.

French physical anthropology centers around the materials so richly offered by France's colonial empire and France's prehistoric sites. The latter have yielded recently in the famous Lascaux Caves paintings of extraordinary number and quality.

In France, anthropological research is more or less limited to Paris. Dr. Paul Rivet, who had succeeded in concentrating different research centers in the Musée de l'Homme, has now been succeeded as director of the latter institution by the well-known paleo-anthropologist, Henri Vallois.

German anthropology in the Eastern Zone has been "marxianised." The two most important German centers, Leipzig and the Berlin Museum, were both located in the Russian Zone. In West Berlin, a valiant effort is made by the Thurnwalds, Kutscher, and others to maintain the Berlin anthropological tradition. Nevertheless, German scientific anthropology is now mainly reduced to the Western Zone. West Germany is a small country in American terms and was utterly destroyed. It is all the more remarkable that German anthropology still appears, as to collections and personnel, second in the world only to the U. S.

Physical anthropology and ethnology (our cultural anthropology) belong usually to two different "faculties" in German universities and are regarded as two independent sciences. Closer are the relations between prehistory (our archeology) and ethnology.

There is little to say about German physical anthropology. Most of its exponents adopted the utterly unscientific racist doctrines of Nazism, under which they prospered. After the occupation of Germany, they were therefore suspended, but now they are slowly coming back into their positions in all Zones. Except for a few men like K. Saller (Munich) and F. Falkenburger (Mainz), German physical anthropology is therefore scientifically or personally without interest. The situation is similar in prehistory.

German ethnology as a discipline never enjoyed the benevolence of the Third Reich. Only a few ethnologists became active party members. Even fewer reflected Nazi ideologies in their writings. Germany was famous for her beautiful ethnological museum buildings, her collections, and specialized libraries. German ethnologists seemed so preoccupied with their collections that some tendencies in German ethnology were criticized as "museum anthropology." The splendid collections have indeed at times

acted as a dead weight on German anthropology, but, I am sure, they will eventually prove to be an asset.

The beautiful museum buildings were, with a few exceptions, a more or less total loss. Some are now partially rebuilt, but they are used for other purposes. Thanks to timely evacuation (an important lesson to us in this time of danger), the greater part of the West German collections have been saved. In some places, the large objects, which could not be evacuated, were lost. In others, the evacuated material disappeared or was destroyed. Specialized libraries have, with a few exceptions, also survived, thanks to evacuation. All libraries suffer very much from lack of the many important foreign materials published, especially in English, during the war and the immediate pre- and postwar periods.

Not many anthropologists were killed during the War, but many have been forced into other professions. They have become bureaucrats, businessmen, craftsmen, *etc.* One has settled as a shamanistic healer.

In the largest centers, like Frankfurt, Hamburg, Munich, and Cologne, a university department and a museum exist, both directed by the same individual. There are numerous museums in non-university towns like Bremen, Luebeck, Mannheim, and Stuttgart. There are active university departments in smaller universities that lack museums, like Tuebingen, Mainz, and Bonn.

The two largest centers are Hamburg and Frankfurt. It is characteristic of the energy with which German ethnologists have carried on under the most trying postwar conditions that the Hamburg Museum, directed by Dr. F. Termer, known for his work on Central American archeology, handprinted the 3-volume monograph by Vicedom and Tischner on the Mbowamb of New Guinea, when no other means of publication were available.

The Frankfurt Frobenius Institute has succeeded in sponsoring several publications since 1945. Its journal, "Paideuma," appears irregularly. The "Zeitschrift für Ethnologie," the famous organ of the German Ethnological Society, also started reappearing in 1950. Publication outlets remain, nevertheless, disporportionately small in Germany.

The Frobenius Institute is also the first German institute that has succeeded in sending out an expedition. Prof. A. E. Jensen and collaborators started field work in Abyssinia late in 1950. Prof. Jensen is known for his earlier field work in Africa and Indonesia. All seven scientific members of the Frankfurt staff have field experience. The interesting results of the Australia expedition of H. Petri and A. Lommal, undertaken shortly before the war, are unfortunately still unpublished, and part of their material was destroyed during the war.

In their general orientation, most German anthropologists, like their French colleagues, without pedantry or slavish dependence, develop an approach first conceived at the beginning of the century, in this case the historical approach. The best way of illustrating this German approach might be to analyze a recent representative sample of German ethnological writing, Prof. A. E. Jensen's "Das Religioese Weltbild einer Fruehen Kultur" (Stuttgart, 1948—The Religious World Conception of an Early Culture.) Dr. Jensen's approach is historical, that is, a primitive culture is approached primarily in order to understand its place and role in the prehistory of mankind. The author agrees in principle that phases of this history can be isolated in the form of "culture areas" or "cultural cycles," but is highly skeptical as to the validity of those "cultural cycles" reconstructed in the past by Frobenius, Graebner, Ankermann, Father Schmidt, *etc.* Following a criticism of Frobenius, he feels that reconstructions have so far been based on statistical work with heterogeneous, mostly material elements (studied in museums) and therefore been condemned to failure in view of the organismic quality of cultures. (This is the "gestalt" approach, entering German ethnology through Frobenius and

Krause in the 1920's and U. S. anthropology through Benedict, Opler, *etc.* in the 1930's.) Jensen bases his reconstruction on mythology, which is more likely to reflect central themes (patterns, configurations, the "weltbild"—world view) of different cultures. He starts with the myth of the killing of the lunar goddess in West Ceram (Indonesia), discovered by himself, marking the beginning of death *and* procreation among men and the cultivation of plants. Many ceremonials, especially puberty ceremonials, enact this myth. Jensen finds the same myth and ceremonials in such different tribes as the Marind-Anim, Kiwai-Papuans, Khond, Californian Indians, Uitoto, Pangwe, Southern Rhodesians. He finds clear remnants of it in the Eleusinian mysteries, and other religious productions of high cultures. These parallels, that cannot be explained by psychology, suggest that widespread existence of an early culture, introducing the domestication of plants and creating this particular myth. Professor Jensen calls this *Kulturkreis* temptatively "lunar" and shows his relations to studies of Frazer and to the "malayonigritic" "equatorial", *etc.*, *Kulturkreis*. Prof. Jensen handles his materials with much skill, perspicacity, and caution.

The most encouraging aspect of German anthropology today, in my mind, is the eager and intelligent young men and women who, in spite of unusual hardships, dedicate themselves to the study of anthropology. This has been the impression of many visitors, especially those who have known a rather different type of German student before World War I and World War II. If they will be given only the smallest chance, we can be confident that German ethnology will have as fine a future as it had a past.

NEW MEMBERS

Elected February 20, 1951

LIFE MEMBERSHIP

Wenner-Gren, Axel L., Swedish Industrialist.

SUSTAINING MEMBERSHIP

Attura, George M., B.E.E., M.E.E., Feedback Systems. President, Industrial Control Co., Long Island City, N. Y.

Babits, Victor Alexander, D.Sc. B.E.E., Radio & Television Engineering. Associate Professor in Electrical Engineering, Rensselaer Polytechnic Inst., Troy, N. Y.

Keener, Paul Douglas, Ph.D., Phytopathology, Mycology. Assist. Prof. of Plant Pathology, University of Arizona, Tucson, Arizona.

Ovesey, Lionel, M.D., B.A., Psychiatry, Psychology. Instructor in Psychiatry, Columbia University, New York, N. Y.

Peck, Paul Norman, M.A., Anatomy, Pathology. Medical Director, Sudler & Hennessey, New York, N. Y.

Posen, Daniel, D.D.S., General Science. Private Practice of Dentistry, New York, N. Y.

Rousselot, Louis M., M.D., Surgery. Director of Surgery, St. Vincent's Hospital, New York, N. Y.

ACTIVE MEMBERSHIP

Adcock, Willis A., Ph.D., B.S., Heterogeneous Catalysis. Senior Chemist, Stanolind Oil & Gas Co., Tulsa, Okla.

Altmann, Franz, M.D., Ear, nose and throat. Assistant Clinical Professor of Otolaryngology, Columbia University, New York, N. Y.

Armistead, Willis W., D.V.M., M.S., Veterinary Medicine & Surgery. Professor of Veterinary Medicine & Surgery, Agricultural & Mechanical College of Texas, College Station, Texas.

Atchley, William Ames, M.D., Medical Research. Visiting Investigator, Rockefeller Inst., for Medical Research, New York, N. Y.

Avery, John Sargent, M.D., Internal Medicine. Research Fellow in Syphiology, New York Hospital, New York, N. Y.

Benham, Rhoda W., Ph.D., M.A., Medical Mycology. Associate Professor of Dermatology, Columbia University, New York, N. Y.

Blatherwick, Norman R., Ph.D., D.Sc., Biochemistry, Director, Biochemical Laboratory, Metropolitan Life Insurance Company, New York, N. Y.

Bolton, Ellis T., Ph.D., Biophysics. Staff Member, Carnegie Institute of Washington, Washington D. C.

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Brescia, Nicholas Joseph, D.D.S., Dental Research. Instructor in Anatomy, Loyola School of Dentistry, Chicago, Ill.

Brod, Judith G., B.A., Biology. Graduate Teaching Assistant, Adelphi College, Garden City, N. Y.

Bromberg, Fred., M.D., General & Traumatic Surgery. Attending Surgeon, Southside Hospital, Bay Shore, L. I., N. Y.

Brown, Charles A., Ph.D., Inorganic Chemistry. Instructor in Organic Chemistry, Harvard University, Cambridge, Mass.

Burnett, Charles H., M.D., Internal Medicine. Professor, Department of Internal Medicine, Southwestern Medical School, Dallas, Texas.

Cagan, Ralph N., M.D., B.A., Metabolism. Medical Resident, Brooklyn Jewish Hospital, Brooklyn, N. Y.

Carhart, Sally Rutherford, M.S., Bacteriology. Bacteriologist, Diagnostic Laboratory, Cook County Hospital, Chicago, Ill.

Carritt, Dayton, E., Ph.D., Analytical Chemistry. Assist. Prof. of Sanitary Engineering & Oceanography, The John Hopkins University, Baltimore, Md.

Caylor, Harvey C., M.D., Medicine & Surgery. Private Practice.

Champetier, Georges, D.Sc., Chimie macromoleculaire. Professeur à la Faculté des Sciences de Paris, Paris, France.

Cirelli, Daniel P., B.S., Biochemistry. Graduate Student, Fordham University, New York, N. Y.

Clow, Allan B., M.C.S., Animal Nutrition. Assistant to General Manager, Lederle Labs., American Cyanamid Co., New York, N. Y.

Cohen, Adolph Irvin, M.A., Physiology. Graduate Student, Columbia University, New York, N. Y.

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De Becze, George I., M.S., Microbiology. Manager of Distillery Central Control Lab., Schenley Distrilleries Inc., Cincinnati, Ohio.

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Dogan, Edith, B.A., Bacteriology, Mycology. Bacteriologist.

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Downes, Elizabeth Fleming, B.S., Anthropology. Editorial Assist., Natural History Magazine, New York, N. Y.

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Gerold, Patricia K., M.S., Histochemistry. Research Assist., Dept. of Zoology, Cornell University, Ithaca, N. Y.

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Gold, Wallace William, M.S., Physics.

Goldberg, Hyman J. V., Dental Research. Research Assoc., Eastman Dental Dispensary, Rochester, N. Y.

Goodman, Fred, B.A., Genetics. Instructor in Biology, Brooklyn College, Brooklyn, N. Y.

Greenberg, Emanuel Martin, M.D., Obstetrics. Clin. Assist. Mt. Sinai Hospital, New York, N. Y.

Greenspan, Ezra M., M.D., Cancer Research. Acting Chief, Clinical Res. Unit, National Cancer Inst., U. S. Marine Hospital, Baltimore, Md.

Greyson, Jerome, B.A., Chemistry. Research Technician, New York State University Medical School, Brooklyn, N. Y.

Gross, Ludvik, M.D., Cancer Research. Chief Cancer Research Lab., Vets. Ad. Hospital, New York, N. Y.

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Herrlich, William E., B.S., Chemistry. Financial Analyst in Trust Investment. Guaranty Trust Co., of New York, N. Y.

Harrison, W. Benton, M.A., B.A., Scientific Methods. Treasurer, General Aniline Film Corp., New York, N. Y.

Harvey Jr., Joseph Paul, M.D., Surgery. Senior Intern, University Hospitals, Cleveland, Ohio.

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Hummeler, Klaus H., M.D., Virology. Fellow in Research, Children's Hospital, Phila., Pa.

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Irons, Edwin N., M.D., Internal Medicine, Bacteriology. Clinical Associate, University of Illinois, Chicago, Ill.

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Kaufmann, Stephen, D.Sc., Organic Chemistry. Director of Production, Syntex S.A., Mexico D.F., Mexico.

Kleinfeld, Morris, M.D., Physiology. Private Practice, Brooklyn, N. Y.

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Samson Jr., Frederick E., B.S., Physiology. Teaching Assistant, University of Chicago, Chicago, Ill.

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Sheehan, John C., Ph.D., Chemistry of Penicillin. Assoc. Prof. of Chemistry, Massachusetts Inst. of Technology, Cambridge, Mass.

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Ushkow, Samuel, Ph.G., Pharmacy, Chemistry. Ampoule Mfg., Endo Products Inc., Richmond Hill, L. I., N. Y.

Velardo, Joseph Thomas, M.S., Endocrinology. Research Assist. in Endocrinology, Harvard University, Cambridge, Mass.

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STUDENT MEMBERSHIP

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